Influence of Humeral Torsion on Interpretation of Posterior Shoulder Tightness Measures in Overhead Athletes

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Objective: To measure the influence of humeral torsion on interpretation of clinical indicators of posterior shoulder tightness in overhead athletes.

Design: Cross-sectional control group comparison.

Setting: A university-based sports medicine research laboratory.

Participants: Twenty-nine healthy intercollegiate baseball players and 25 college-aged control individuals with no history of participation in overhead athletics were enrolled.

Intervention: In all participants, bilateral humeral rotation and humeral horizontal adduction variables were measured with a digital inclinometry. Bilateral humeral torsion was measured with ultrasonography.

Main Outcome Measures: Group and limb comparisons were made for clinical indicators of posterior shoulder tightness (humeral rotation and horizontal adduction variables) and humeral torsion variables. The relationship between humeral torsion and clinical indicators of posterior shoulder tightness were established.

Results: The dominant limb of the baseball players demonstrated greater humeral torsion, and less internal rotation and total rotation range of motion, compared with control participants and the nondominant limb in both groups. Once corrected for torsion, no group or limb differences in internal rotation were present. Statistically significant relationships existed between the amount of humeral torsion and measures of posterior shoulder tightness.

Conclusions: Although limb differences in clinical indicators of posterior tightness exist in healthy overhead athletes, these measures appear to be influenced by humeral torsion rather than soft tissue tightness. Once torsion is accounted for, the limb differences observed clinically were minimal in healthy overhead athletes. When possible, accounting for humeral torsion when interpreting clinical measures of posterior shoulder tightness may aid in treatment decisions.

Key Words: shoulder, humeral torsion, ultrasound, range of motion

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INTRODUCTION

Measurement of passive humeral rotation in overhead athletes (especially throwing athletes) is a common clinical practice to identify contracture and tightness present in the posterior shoulder capsule and musculature. This posterior shoulder tightness is believed to alter glenohumeral arthrokinematics[1–3] and is linked to the presence of shoulder pain and injury.[1–8] During clinical evaluation, this tightness is commonly assessed by evaluating the presence of decreased internal rotation, total humeral rotation, and horizontal adduction in the dominant limb compared with the nondominant limb.[4,6,9–11]

The amount of humeral rotation range of motion that is quantified during clinical examination is a function of both soft tissue restraints[12–17] as well as the osseous geometry, specifically humeral torsion.[18–21] The contribution by osseous geometry on humeral rotation range of motion may be especially large in overhead athletes given the torsion moments that are placed on the humerus during the act of throwing.[22] The dominant limb of throwing athletes has repeatedly been shown to have more humeral torsion,[18–20,23,24] shifting the glenohumeral rotation arc toward the external rotation direction, thus decreasing internal rotation.[19] This decreased internal rotation results in a deceiving appearance of having posterior shoulder tightness, prompting clinicians to prescribe a stretching program[25,26] when in fact the soft tissue tightness may not be present. Therefore, simply measuring range of motion without regard to humeral torsion may confound the decisions made by clinicians.

As an alternative to using a humeral rotation assessment to identify posterior shoulder tightness, variations in measurements of humeral horizontal adduction range of motion have also been described.[6,9–11] Although these measures do not involve humeral rotation movement, they may still be affected given that humeral orientation may influence the orientation of

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the fibers and the tension pre-existing within the posterior shoulder capsule and musculature partially affecting the measurement.[27,28]

Given the important role posterior shoulder tightness plays in injury in overhead athletes, efforts to improve the assessment technique for tissue tightness should be made. Clinical assessments of humeral rotation range of motion that account for humeral torsion may provide a better means of quantifying the soft tissue contribution to the altered range of motion. Ultrasonography provides a noninvasive means of quantifying humeral torsion.[24,29] Therefore, interpreting range-of-motion values with humeral torsion may be a suitable way to evaluate posterior shoulder tightness. The purpose of this study was to measure the influence of humeral torsion on interpretation of clinical indicators of posterior shoulder tightness in overhead athletes.

METHODS

Subjects

Twenty-nine intercollegiate baseball players (age = 19.5 ± 1.0 years; height = 183.5 ± 8.0 cm; body mass = 87.5 ± 11.1 kg) and 25 college-aged healthy control individuals (age = 20.0 ± 1.1years; height = 182.3 ± 8.4 cm; body mass = 81.8 ± 12.4 kg) with no history of participation in overhead athletics were enrolled. All baseball players were collegiate-level Division I players who have played for at least 10 years (14.8 ± 1.9 years). All the players started competing in baseball during adolescence when the torsional influences from throwing are high.[22]

Procedures

All participants attended one laboratory testing session where university-approved informed consent was provided and humeral rotation range of motion, humeral horizontal adduction range of motion, and humeral torsion were assessed bilaterally by two testers. The testers were not blinded to group allocation.

Bilateral humeral rotation range of motion was measured passively with a digital inclinometer (The Saunders Group, Inc., Chaska, MN). The participants lay supine on a treatment table with 90° of shoulder abduction and elbow flexion and the forearm pointing toward the ceiling perpendicular to the plane of the treatment table (defined as 0° of humeral rotation). A small towel roll was placed under the humerus to maintain its position in the frontal plane. One examiner passively internally rotated the humerus until end range was appreciated with one hand while providing scapular stabilization against the treatment table through a posteriorly directed force at the acromion with the other hand, thereby isolating movement to glenohumeral joint motion. At end range, a second investigator aligned the digital inclinometer with the forearm and recorded the angle of the forearm with respect to vertical as the internal humeral rotation angle. External rotation was assessed using identical methodology with the exception of the direction of motion. This was repeated for a total of three trials for each limb. Before this study, reliability (intraclass correlation coefficients) and precision (standard error of measurement) of the humeral rotation range-of-motion assessments was established, yielding intrasession, intersession, and intertester reliability coefficients ranging from 0.93 to 0.97 with an average error of approximately 1.9°.[30]

Humeral horizontal adduction (HHA) was assessed using our previously reported supine methodology.[10] Each participant lay supine on the treatment table where one tester stood beside the treatment table of the shoulder being tested while the participant lifted his or her shoulder off the table. The tester then placed one hand under the scapula, pressing the thenar eminence against the lateral border of the scapula, stabilizing the scapula in a maximally retracted position. The tester then used the other hand to passively move the participant's arm into horizontal adduction while maintaining neutral humeral rotation. At the end range of horizontal adduction, the second tester recorded the angle formed between the humerus and the horizontal plane using a digital inclinometer. A total of three trials were recorded for each limb. The investigators have previously established the reliability (intraclass correlation coefficient = 0.91), precision (standard error of mean = 1.1°), and construct validity of using this supine assessment.[10]

Humeral torsion was assessed using a modification of the indirect ultrasonographic techniques described by both Whiteley et al[24] and Yamamoto et al.[29] Participants lay supine on a treatment table with 90° of shoulder abduction and elbow flexion. A tester positioned a 4-cm linear array ultrasound transducer (LOGIQe; General Electric, Milwaukee, WI) on the participant's anterior shoulder with the ultrasound transducer level with the plane of the treatment table (verified with a bubble level) and aligned perpendicular to the long axis of the humerus in the frontal plane (Fig. 1A). The second tester then rotates the humerus so that it is positioned with the bicipital groove appearing on the center of the ultrasound image with the line connecting the apexes of greater and lesser tubercles parallel to the horizontal plane (Fig. 1B). A grid was applied to the display of the ultrasound unit to aid examiners with positioning of the humeral tubercles. The second tester then placed a digital inclinometer on the ulnar side of the forearm, pressing firmly against the ulna, and recorded the forearm inclination angle with respect to horizontal (Fig. 1A). Because the ulna extends perpendicular to the elbow epicondylar axis (line connecting the medial and lateral epicondyles), this angle reflects the angular difference between the epicondylar axis (distal humerus) and the line perpendicular to the line connecting the apexes of the greater and lesser tubercles (proximal humerus), thus representing humeral torsion. Three trials were performed bilaterally. Before this study, the investigators established reliability in a group of 30 college-aged students, yielding intrasession, intersession, and intertester reliability coefficients ranging from 0.96 to 0.98 with an average of 2.3° of measurement error.

F1

Outcome Measures

Clinical measures of humeral internal (clinical IR) and external range of motion (clinical ER) were defined as the three trial mean of the angle between end range of passive internal (or external) rotation and a starting position where the forearm points superiorly (perpendicular to the plane of the treatment

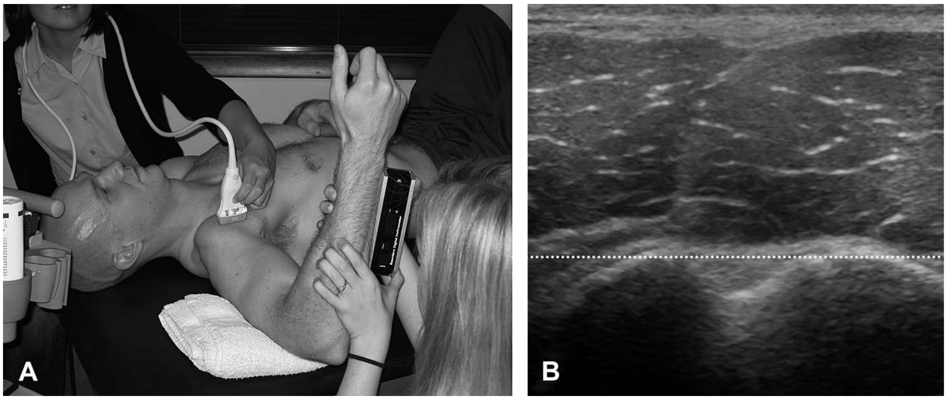

FIGURE 1. (A) Ultrasonographic assessment of humeral torsion. (B) Ultrasonographic image of the upper humerus where the humeral tubercles are pointing superiorly.

table). Glenohumeral internal rotation deficit (GIRD), a common clinical indicator of posterior shoulder tightness, was calculated as the angular difference between the dominant (throwing limb) clinical IR and nondominant (nonthrowing limb) clinical IR.[4,10] External rotation gain (ERG) was calculated as the angular difference between the dominant (throwing limb) clinical ER and nondominant (nonthrowing limb) clinical ER. Glenohumeral rotation total range of motion (total ROM) was calculated as the sum of clinical IR and clinical ER. Total ROMΔ was calculated as the difference between the dominant (throwing limb) total ROM and nondominant (nonthrowing limb) total ROM. Humeral horizontal adduction was calculated as the three-trial mean of the horizontal adduction angle relative to the plane of the treatment table.[10] Decreased humeral adduction range of motion is commonly reported as a clinical indicator of posterior shoulder tightness.[4,6,9–11,25,31] HHAΔ was quantified as the angular difference between the dominant (throwing limb) and nondominant (nonthrowing limb) HHA. Humeral torsion (HT) was calculated as the three-trial mean of the humeral rotation angle when the humerus was placed in an anatomic neutral, standardized position where the humeral tubercles are parallel to the plane of the treatment table. The larger the humeral rotation angle (relative to the plane of the treatment table), the more torsion is present.[24] Humeral torsion difference (HTΔ) was calculated as the mean difference between dominant and nondominant limb torsion. From the humeral torsion data collected, internal and external rotation range of motion corrected for humeral torsion (adjusted IR/ER) were calculated. Adjusted IR and ER were defined as the available range of motion in the internal and external rotation directions from the humeral torsion position (anatomic neutral position where the line connecting the apexes of the lesser and greater tubercles is parallel to the horizontal plane). From adjusted IR and ER data, adjusted GIRD and ERG were calculated as the angular difference between the dominant and nondominant limbs. Adjusted GIRD represents the side-to-side difference in soft tissue extensibility of the posterior shoulder. All variables are represented in Figure 2. F2

Analysis

Two-way analysis of variance with Bonferroni post hoc analyses was used to compare clinical IR and ER, adjusted IR and ER, total ROM, HHA, and HT across groups (overhead athlete versus control participants) and limbs (dominant versus nondominant). Independent *t* tests were used to determine if significant group differences exist in GIRD, adjusted GIRD, ERG, adjusted ERG, total ROMΔ, HTΔ and HHAΔ, because these measures account for limb difference. Pearson product moment correlation analyses were used to determine the relationships between common clinical indicators of shoulder tightness (GIRD, ERG, HHAΔ, total ROMΔ), humeral torsion difference (HTΔ), and measures of posterior tightness adjusted for torsion (adjusted GIRD and adjusted ERG). An alpha level of 0.05 was set a priori for statistical analyses.

RESULTS

Descriptive statistics for all variables appear in Table 1. T1 Significant group by limb differences were present for clinical IR ($P < 0.001$), total ROM ($P = 0.002$), HT ($P < 0.001$), and HHA ($P = 0.002$). The dominant limb of the baseball players demonstrated greater humeral torsion, and less internal rotation and total ROM, compared with control participants and the nondominant limb in both groups. For clinical ER, although the interaction was insignificant ($P = 0.816$), significant limb ($P < 0.001$) and group ($P < 0.001$) main effects were present. Regardless of group, the dominant limb exhibited more clinical ER than the nondominant limb. The baseball players also exhibited more clinical ER compared with the control participants when the data were collapsed across limb. Once corrected for torsion, no group or limb differences in internal rotation (adjusted IR) ($P = 0.508$) were present. The baseball players did exhibit more adjusted ER ($P = 0.002$) in their nondominant limb compared with their dominant limb and control participant limbs.

For clinical measures of shoulder flexibility that account for limb (GIRD, ERG, total ROMΔ, HHAΔ), the baseball players demonstrated significantly more GIRD ($P < 0.001$), total ROMΔ ($P = 0.002$), and HHAΔ ($P = 0.002$). No differences were present in ERG ($P = 0.816$). Once corrected for humeral torsion, the baseball players demonstrated more adjusted ERG ($P = 0.002$) but no differences in adjusted GIRD ($P = 0.508$).

Statistically significant relationships existed between HTΔ and GIRD ($r = –0.66$, $P < 0.001$), HHAΔ ($r = –0.29$,

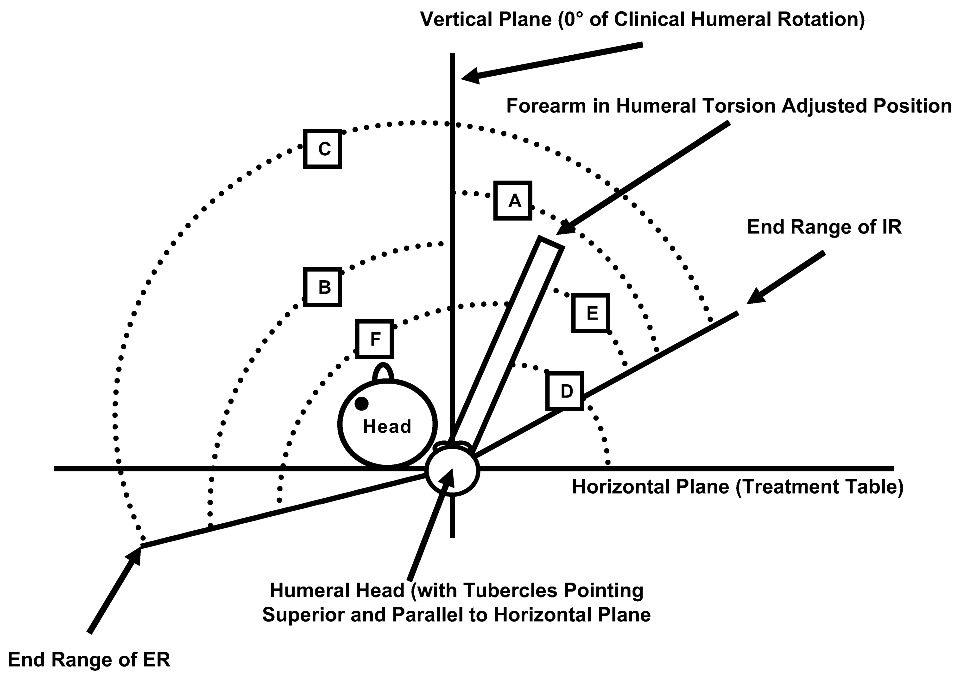

FIGURE 2. Humeral internal rotation and humeral torsion variables assessed. (A) Clinical IR, (B) clinical ER, (C) total ROM, (D) humeral torsion, (E) adjusted IR, and (F) adjusted ER. IR, internal rotation; ER, external rotation; ROM, range of motion.

$P = 0.017$), and total ROMΔ ($r = -0.54$, $P < 0.001$). Total ROMΔ was significantly correlated with GIRD ($r = 0.80$, $P < 0.001$) and ERG ($r = 0.39$, $P < 0.001$) before torsion adjustment, but only with adjusted GIRD after torsion correction ($r = 0.71$, $P < 0.001$).

DISCUSSION

Consistent with previous research,[4,5,10,11,32,33] this study demonstrated differences in clinical measures of posterior shoulder tightness in overhead athletes when compared with control participants. Traditionally, when internal rotation range of motion is interpreted to be decreased in the dominant shoulder, the deficit is thought to result from decreased tissue extensibility of the posterior shoulder. However, as previously stated, glenohumeral joint rotation range of motion is affected by both tissue flexibility and osseous geometry. The current study demonstrated that on average, the dominant limb of overhead athletes displayed approximately 15° more humeral torsion than its nondominant limb and approximately 13° more

TABLE 1. Descriptive Statistics

	Overhead Participants				Control Participants			
	Dominant		Nondominant		Dominant		Nondominant	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Clinical IR (°)	36.9	7.9	51.2	9.7	48.7	11.1	53.4	8.8
Clinical ER (°)	134.8	9.6	129.8	8.5	123.3	10.5	118.7	12.3
Total ROM (°)	171.7	12.8	181.1	11.3	172.0	11.8	172.2	15.4
HHA (°)	99.8	6.1	103.9	4.2	100.2	8.3	99.3	9.7
Humeral torsion (°)	83.0	11.0	65.3	11.4	70.5	13.5	64.3	12.3
Adjusted IR (°)	29.8	10.0	26.5	11.9	29.3	13.0	27.7	10.5
Adjusted ER (°)	141.8	10.3	154.5	11.4	142.8	18.6	144.5	15.7
GIRD (°)	−14.4	9.6			−4.7	9.3		
ERG (°)	4.9	8.1			4.5	5.5		
Adjusted GIRD (°)	3.3	9.7			1.6	9.5		
Adjusted ERG (°)	−12.7	12.2			−1.7	12.1		
HHAΔ (°)	−4.0	5.2			0.9	5.7		
HTΔ (°)	17.7	9.5			6.3	1.2		
Total ROMΔ (°)	−9.4	10.6			−16.6	9.8		

SD, standard deviation; GIRD, glenohumeral internal rotation deficit; ERG, external rotation gain; ROM, range of motion; HHA, humeral horizontal adduction; IR, internal rotation; ER, external rotation; HT, humeral torsion; Δ, difference.

than individuals with no history of overhead athletic participation. This indicates that measures of range of motion may be greatly affected by humeral torsion and that bilateral differences in these measures may not accurately reflect differences in soft tissue restriction. Once torsion was accounted for, the limb and group differences in humeral rotation range-of-motion variables were much less pronounced. In addition, the moderate relationship ($r = -0.657$) between GIRD and HTΔ suggests that the humeral rotation variables are strongly influenced by the amount of torsion that is present.

To account for the contribution that torsion plays in humeral rotation variables, we adjusted the humeral internal and external rotation variables (adjusted IR and ER) by redefining neutral humeral position based on each participant's humeral torsion data. In the current study, the baseball players had less dominant-limb clinical IR compared with control participants but had no differences in IR once torsion was accounted for. Conceptually, the adjusted IR represents the amount of internal rotation allowed by soft tissue flexibility. In a case in which the clinically measured internal rotation appears decreased, yet the adjusted IR is conserved, the patient's tissue flexibility may be normal. Conversely, when the clinical IR appears normal, yet the adjusted IR is significantly diminished, the patient may have a soft tissue tightness that may be improved by performing stretching exercises. The current study only examined asymptomatic participants. Replication of this study with injured overhead athletes who are apt to have increased posterior shoulder tightness would provide valuable information clinically.

An alternative method to assess posterior shoulder tightness is the measurement of humeral horizontal adduction range of motion. In the current study, HHAΔ was more correlated with humeral torsion difference than any of the other range-of-motion variables that account for limb, suggesting that the side-to-side differences seen clinically may be influenced by the humeral torsion as well. The horizontal adduction range-of-motion measurements are performed with the upper arm and forearm maintained in the transverse plane with the arm in 0° of humeral rotation (not corrected for torsion). The varying degree of humeral torsion present when the humerus is in this standardized testing position may alter the orientation of the fibers and the tension pre-existing within the posterior shoulder structures (capsule and musculature), which may affect the measurement. This influence of humeral torsion on capsular and muscle tension may account for the moderate to poor ability of humeral horizontal adduction methods to predict humeral internal rotation range of motion.[6,9–11] As such, the posterior shoulder tightness that is being identified by those measures may be confounded by the amount of torsion that is present as well.

Given the influence that humeral torsion has on measures of posterior shoulder tightness comparison of the tightness measurements between individuals may not be appropriate. However, a decrease in clinical measures of internal rotation and horizontal adduction over time may be a better indicator estimator of tightness within an individual whose bone is mature. Assuming that the humeral torsion does not change after skeletal maturity is reached, any change in clinical internal rotation or horizontal adduction measurement can be attributed to the change in soft tissue tightness. Baseline measurement of the internal rotation and horizontal adduction range of motions during preseason may allow the clinician to detect changes in tissue tightness over the course of the season regardless of the amount of torsion present.

Side-to-side differences in total humeral rotation range of motion may be more reflective of soft tissue tightness in the shoulder given that total range of motion should not be affected by the torsion present. Any internal rotation lost from humeral torsion should be counteracted by the external rotation gained. Therefore, any deficit in total rotation range of motion seen side to side should be reflective of soft tissue restriction limiting the motion rather than torsion. Interestingly, in the current study, the results showed that total ROMΔ is more related to differences in external rotation than in internal rotation once corrected for humeral torsion. This may suggest that the deficit in total humeral rotation arc may indicate tightness of the musculature limiting glenohumeral external rotation such as pectoralis major and latissimus dorsi muscles instead of the posterior shoulder structures. Instead of improving posterior shoulder flexibility, stretching of the anterior shoulder muscles may be recommended as well for those overhead athletes with total rotation range-of-motion deficits. This is a finding that warrants more exploration in injured athletes given the participants of the current study were healthy at the time of testing.

Like previous work using radiologic measures,[18–20,23] these ultrasonographic-obtained results demonstrate increased humeral torsion on the dominant throwing limb when compared with the nondominant limb and control participants. Although radiologic measures are believed to be the gold standard for measuring torsion, they do involve ionizing radiation to perform, making clinical use more difficult to justify. Ultrasonographic assessment of torsion provides a reliable and precise noninvasive means to measure torsion clinically.[24] The differences between limbs and groups identified in this study as well as others[24] provide a level of construct validity for the noninvasive ultrasonographic methodology given that these results mimic published results that use radiologic methodology.[18–20,23] The use of ultrasonography provides a quick, noninvasive means to clinically quantify the amount of humeral torsion present, aiding in interpretation of the humeral rotation range-of-motion measurements. For example, when internal rotation deficits are identified during a clinical examination, clinicians can use ultrasonography to determine if the deficits are a result of bony geometry or soft tissue restriction. In cases in which soft tissue restriction is the culprit, stretching can be implemented. The authors recognize that ultrasonography may not be readily available to many clinicians who evaluate overhead athletes. When measurement of humeral torsion is not available, obtaining baseline measurement of humeral rotation and horizontal adduction range of motion during preseason may allow the clinician to detect changes in tissue tightness over the course of the season.

CONCLUSIONS

The results of this study demonstrate humeral rotation range-of-motion and horizontal adduction differences between the dominant and nondominant limb of healthy overhead athletes and control participants. Yet those differences appear to be highly influenced by the amount of humeral torsion that is present. Once humeral torsion was accounted for, these limb differences were much less pronounced. The humeral rotation range of motion that is present after accounting for humeral torsion may better represent the contribution of soft tissue flexibility to humeral rotation range of motion.

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